CLAIMS

1. Power generator apparatus for converting an alternating current (AC) input to a direct current (DC) output, the apparatus comprising:

a clock generator;

a power switching device gated by the clock generator and coupled to the alternating current (AC) input to generate regulated DC output power;

a memory device storing digitized reference data; and

means for comparing the alternating current (AC) input and DC output to effect power circuit function between operating in a first phase at a first frequency and operating in a second phase at a second frequency;

said reference data in said memory device being used to continuously pulse-width modulate (PWM) a duty cycle of a gating signal from the clock generator to the power switch during said second phase.

2. The power generator apparatus according to claim 1 including means for switching from a fixed duty ratio to a continuously pulse-width modulated (PWM) duty ratio of the gating signal and in transitioning from a first frequency to a second frequency.

3. The power generator apparatus according to claim 1 wherein the AC input current is substantially in phase and in waveshape relative to the AC input voltage such that the power factor presented back to the utility is near unity.

4. The power generator apparatus according to claim 1 wherein said first phase at said first frequency is operating in flyback mode and said second phase is operating in both flyback and voltage mode.

5. The power generator apparatus according to claim 1 wherein both said first and said second phases are operated in flyback mode.

6. The power generator apparatus according to claim 1 wherein the duty cycle of said first phase at said first frequency is modulated by an error signal comprising the difference between a first voltage which is the regulated output voltage V_O and a second reference voltage V_{REF} such that the duty cycle is varied to maintain a constant output voltage under varying loads.

7. The power generator apparatus according to claim 1, wherein the power switching device is operated at a maximum of 50% duty ratio at full load during the first phase.

8. The power generator apparatus according to claim 1 wherein the input to output voltage ratio is in a range of 5:1 or more.

9. The power generator apparatus according to claim 2 wherein the means for switching in transitioning from the first frequency to the second frequency in the second phase includes means for comparing a rectified input AC voltage and a reference point FCOP to minimize distortion and maintain near unity power factor.

10. The power generator apparatus of claim 1, wherein said stored digitized reference data is a time sequence representation of a string of duty cycles which the power switching device must operate with in accordance with the characteristics of the AC input voltage to PWM the duty cycle.

11. The power generator apparatus of claim 2, in which the switching means includes controls operable such that said first phase of operation is when the value of the output voltage reflected back to the input is higher than the absolute value of the instantaneous AC input voltage and said second phase of operation is when the value of the output voltage reflected back to the input is lower than or equal to the absolute value of the instantaneous AC input voltage, wherein during said second phase the operating frequency transitioning from said first frequency to said second frequency is higher than said first frequency.

12. The power generator apparatus according to claim 1, wherein the switching frequency for operating said first phase is equal to approximately 12.5 kHz for 50 Hz to 60 Hz utility.

13. The power generator apparatus according to claim 1, wherein the switching frequency for operating said first phase is equal to approximately 80 kHz for 400 Hz utility.

14. The power generator apparatus of claim 1, wherein said second frequency is approximately twice the said first frequency.

15. The power generator apparatus of claim 1, wherein said first phase of operation is approximately centered around a zero-crossing of the AC input waveform and wherein said second phase of operation is present in the rest of the input AC cycle complementary thereto.

16. The apparatus of claim 1 further comprising:

a transformer including a primary winding in series with the power switching device and a secondary winding;

plural diodes operatively coupled to said primary winding to effect rectification of the AC input;

plural diodes operatively coupled to said secondary winding to perform a rectification function on the output of the secondary winding;

an inductor operatively coupled to the output of said plural diodes; and

a capacitor across the output to be connected in parallel with the load.

17. The apparatus of claim 16 wherein the rectification function on the output of the secondary winding of the transformer is accomplished through using either Schottky diodes or synchronous rectification.

18. The apparatus of claim 16 wherein said inductor on the secondary having terminals connected to the cathode of each of the top bridge rectifier diodes; and the cathode of the top bridge rectifier diode attached to the negative polarity of the secondary winding of the transformer further connecting to the output capacitor to equally share in delivering energy to the load by the transformer and the secondary inductor in phase 2 operation.

19. The apparatus according to claim 18 in which the transformer and inductor are mutually sized to share energy equally to reduce weight and volume of the transformer and the inductor.

20. Power generator apparatus for converting an alternating current (AC) input to a regulated direct current (DC) output, the apparatus comprising:

said power generator circuit including a single power switching device coupled to said AC input for generating regulated DC output power;

a clock generator providing a clock signal;

means for comparing the AC input and DC output to effect power circuit function by varying the clock rate between operating in a first phase at a first fixed frequency and operating in a second phase wherein said first fixed frequency transitions to a second fixed frequency;

a memory device storing at least representative portions of digitized reference data; and

control means using said data to continuously pulse-width modulate the duty cycle of the clock signal to said power switching device during said second phase.

21. The power generator apparatus of claim 20 wherein the second operating frequency of the second phase is higher than the operating frequency of the first phase leading to reduced peak currents and stresses in the power generator circuit.

22. The power generator apparatus of claim 21 including a transformer wherein the second operating frequency of the second phase is higher than the operating frequency of the first phase leading to reduction in system weight and volume.

23. The power converter apparatus of claim 20 in which the clock generator is operative to employ two discrete frequencies in its operation within any given AC cycle to spread the noise spectrum and reduce the magnitude of its total harmonic content and EMI/RFI effects.

24. The power converter apparatus according to claim 20 further comprising:

a transformer including a primary winding and a secondary winding;

plural diodes operatively coupled to said primary winding;

plural diodes operatively coupled to said secondary winding to effect rectification;

a single power switching device operatively coupled to said plural diodes of said primary winding;

an inductor operatively coupled to said secondary winding and said plural diodes; and

a capacitor connected at the output in parallel with the load; wherein

the converter apparatus operating in flyback mode in a first phase at a first frequency when the output voltage reflected back to the input is higher than the absolute value of the instantaneous AC input voltage and the converter apparatus operating in a second phase in a combination of forward and flyback mode wherein the operating frequency transitioning from said first frequency to a second frequency when the output voltage reflected back to the input is lower than or equal to the absolute value of the instantaneous AC input voltage.

25. The apparatus of claim 24 wherein said inductor on the secondary having terminals connected to the cathode of each of the top bridge rectifier diodes; and the cathode of the top bridge rectifier diode attached to the negative polarity of the secondary winding of the transformer further connecting to the output capacitor to equally share in delivering energy to the load by the transformer and the secondary inductor in phase 2 operation.

26. The power converter apparatus according to claim 24 wherein the duty cycle of said first phase at said first frequency is maintained constant corresponding to a given load and the second phase is continuously pulse-width modulated.

27. The power converter apparatus according to claim 24, wherein the second frequency is approximately an integer multiple of the first frequency.

28. The power converter apparatus according to claim 24, wherein the first phase of operation is approximately centered around a zero-crossing of the AC input waveform and wherein the second phase of operation is complementary thereto.

29. The power generator apparatus according to claim 20 in which the control means utilizes duty cycle control in conjunction with two discrete operating frequencies wherein the duty cycle in phase 1 is fixed for a fixed load and varies when the load varies.

30. The power generator apparatus according to claim 29 further comprising:

a transformer including a primary winding and a secondary winding;

plural diodes operatively coupled to said primary winding;

plural diodes operatively coupled to said secondary winding;

a single power switching device operatively coupled to said plural diodes of said primary winding;

an inductor operatively coupled to said secondary winding and said plural diodes; and

a capacitor connected at the output in parallel with the load; wherein

the converter apparatus operating in flyback mode with a fixed duty cycle corresponding to the given load, when the output voltage reflected back to the input is higher than the absolute value of the instantaneous AC input voltage and the converter apparatus operating in a combination of flyback and forward conversion modes, with pulse-width modulated duty cycle, when the output voltage reflected back to the input is lower than or equal to the absolute value of the instantaneous AC input voltage.

31. The power generator apparatus according to claim 30 wherein the THC is between 1% to 2%.

32. The power generator apparatus according to claim 20 wherein the control means is integrated into an integrated circuit or a compact hybrid circuit to define a compact intelligent module.

33. The power generator apparatus according to claim 20 wherein the control means employs a control scheme which continuously compares the AC input with the regulated output to effect power control function between operating in a first phase at a first frequency when the output reflected back to the input is higher than the absolute value of the AC input and operating in a second phase wherein the operating frequency transitioning from said first frequency to a second frequency when the output reflected back to the input is lower than the instantaneous AC input within a cycle.

34. The power generator according to claim 33 wherein the first phase is operated in flyback mode and the second phase is operated in a combination of flyback mode and forward mode.

35. The power generator according to claim 33 wherein said apparatus is continuously operated in the flyback mode.

36. The power converter apparatus according to claim 22 wherein the input to output transformation is adjusted to have high current and low voltage capability suitable for charging batteries.

37. An intelligent power module having high level integration and compact physical size, comprising:

a power stage having a base plate forming a substrate,

said substrate comprising thermally conducting insulative material forming a heat-sink for efficient removal of heat generated from said module,

said insulative substrate further comprising top layer metal patterned to form internal connections and patterns to receive power components and bonding wire interconnections, and

said power stage further comprising connectors to receive AC input power and control signals from the control stage, and to provide regulated DC power to external loads,

said control stage comprising one or more PCB boards insulatively supported over said power stage,

said PCB board further comprising SMD components mounted thereon to form the control circuit function, and

small signal connectors to provide control signals to said power stage, connectors to external bias power source, and connectors to user provided control circuit inputs external to said module,

an outer wall for mechanical protection,

conformal coating over the substrate assembly, and

resin top layer to fill the cavity,

said connectors are positioned adjacent the outer wall for ease of access.

38. An intelligent power module according to claim 37 where the base plate is either IMS, DBC on BeO, Alumina, or AlN.

39. An intelligent power module according to claim 37 wherein the power stage substrate assembly comprises rectifier diodes for input rectification, a single power semiconductor switch, diodes for output rectification, and a shunt resistor for sensing.

40. An intelligent power module according to claim 37 wherein the control stage employs a control strategy of two phase operation in which the first phase operates at a first fixed frequency and the second phase operating at a second fixed frequency different from the first fixed frequency.

41. A method for AC–to-DC power conversion comprising:

inputting AC Power at a predetermined AC frequency and voltage V_{ac};

full-wave rectifying the input AC power to produce a full-wave rectified voltage V_i having an amplitude proportional to absolute value V_{ac};

applying voltage V_i across a primary of a transformer in series with a gate-controlled switch to produce a current I_M;

coupling a secondary of the transformer to an output rectifying bridge to produce a regulated output voltage V_o across an output capacitor C_o to a load;

comparing input voltage V_i with a voltage V_o' where $V_o' = V_o$ (N1/N2) and N1/N2 is the inverse turns ratio of the transformer;

if V_i is less than V_o', then clocking the gate-controlled switch at a first fixed frequency f_1, so that current I_M is a discontinuous flyback current; and

if V_i is greater than V_o', then clocking the gate-controlled switch at a second fixed frequency f_2, where f_2 is unequal to f_1 and the current I_M is a discontinuous flyback and forward current.

42. A method according to Claim 41, in which f_2 is greater than f_1.

43. A method according to Claim 41, in which f_2 is approximately an integer multiple of f_1.

44. A method according to claim 41, in which, when clocking at f_1 and for an invariant load, the switch is clocked at a fixed duty ratio.

45. A method according to Claim 44 in which the duty cycle has a maximum of 50 percent.

46. A method according to Claim 41, in which, when clocking at f_1, and for a load which is increasing, the switch is clocked at a proportionately increasing duty ratio.

47. A method according to Claim 46 in which the duty cycle has a maximum of 50 percent.

48. A method according to Claim 41, in which, when clocking at f_1, as V_i increases, the current I_M has an average in the discontinuous flyback current which increases proportionately to voltage V_i.

49. A method according to claim 41, in which, when clocking at f_2, the switch is clocked at a duty cycle which is continuously pulse-width modulated with pulses whose duty ratio D is proportionate to the square root of $1/(A + B/V_i)$ where A and B are constants dependent on primary and secondary inductance values, the transformer turns ratio and the output voltage.

50. A method according to Claim 49, in which the maximum duty ratio is 50 percent.

51. A method according to Claim 41, in which the output rectifying bridge includes an inductor positioned in series with the secondary of the positive polarity terminal of the transformer through a diode to store and discharge energy during a forward mode of operation of the bridge.

52. A method according to Claim 51, in which an inductance L of the inductor is proportioned to an inductance L_1 of the primary of the transformer to apportion energy supplied to the load between the inductor and the transformer.

53. A method according to Claim 51, in which the frequency f_2 is selected in proportion to one or more of the size and rating of the transformer.

54. A method according to Claim 41, in which the comparing step between V_i and V_o' during each cycle of the input AC power alternates the clocking frequency between two discrete values f_1 and f_2 to synthesize the regulated output voltage V_o in relation to a reference voltage.

55. A method according to Claim 51, in which the load is a reactive load and the inductor and transformer are proportioned so that a power factor as seen by the input AC power is close to unity.

56. A method according to Claim 41 including, during valleys of the rectified input AC voltage, operating in flyback mode with a fixed duty cycle and a fixed first frequency at a given load with a maximum duty cycle of 50% at full load, and when the rectified input AC voltage exceeds the reflected output voltage, operating in flyback as well as the forward conversion mode at the second fixed frequency which is a multiple of the first frequency while modulating the duty cycle continuously.

57. A method according to claim 41, in which, when operating at the second frequency f_2, the switch is clocked at a duty cycle which is continuously pulse-width modulated with pulses whose duty ratio D is in accordance to Equation (39)

$$D = \sqrt{\frac{V_m Sin\theta_1}{8\left\{2.5V_m Sin\theta - 2\left(\frac{N_1}{N_2}\right)V_0\right\}}}.$$